# Big Sky Carbon Sequestration Partnership: Overview and Focus on Geological Sequestration Opportunities

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**Idaho Carbon Advisory Committee**
**Tues Nov 28, 2006**

Partnership Goals: **Develop infrastructure to support and enable future carbon sequestration deployment in region, and address economic, political and regulatory issues**

Specific activities:

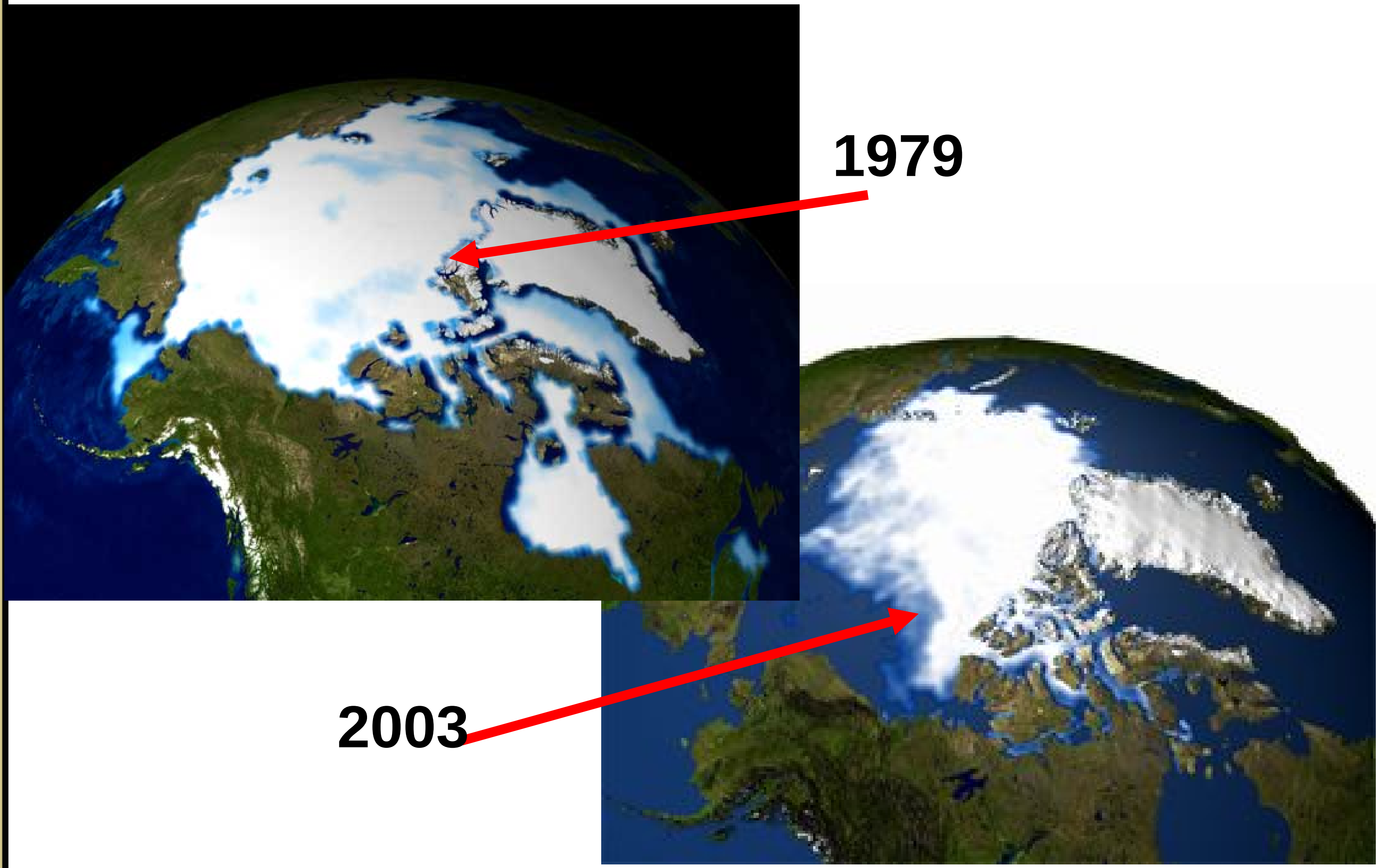
(i) Assessment of sequestration potential (Phase I)

(ii) Deployment of sequestration field validations and Economic assessments of sequestration options and opportunities for CO2 emission offsets (Phase II)

(iii) Plans for large scale sequestration injection(s) (Phase III)

Web site: www.bigskyco2.org

# Signs of Climate Change are All Around Us




24 October 2006

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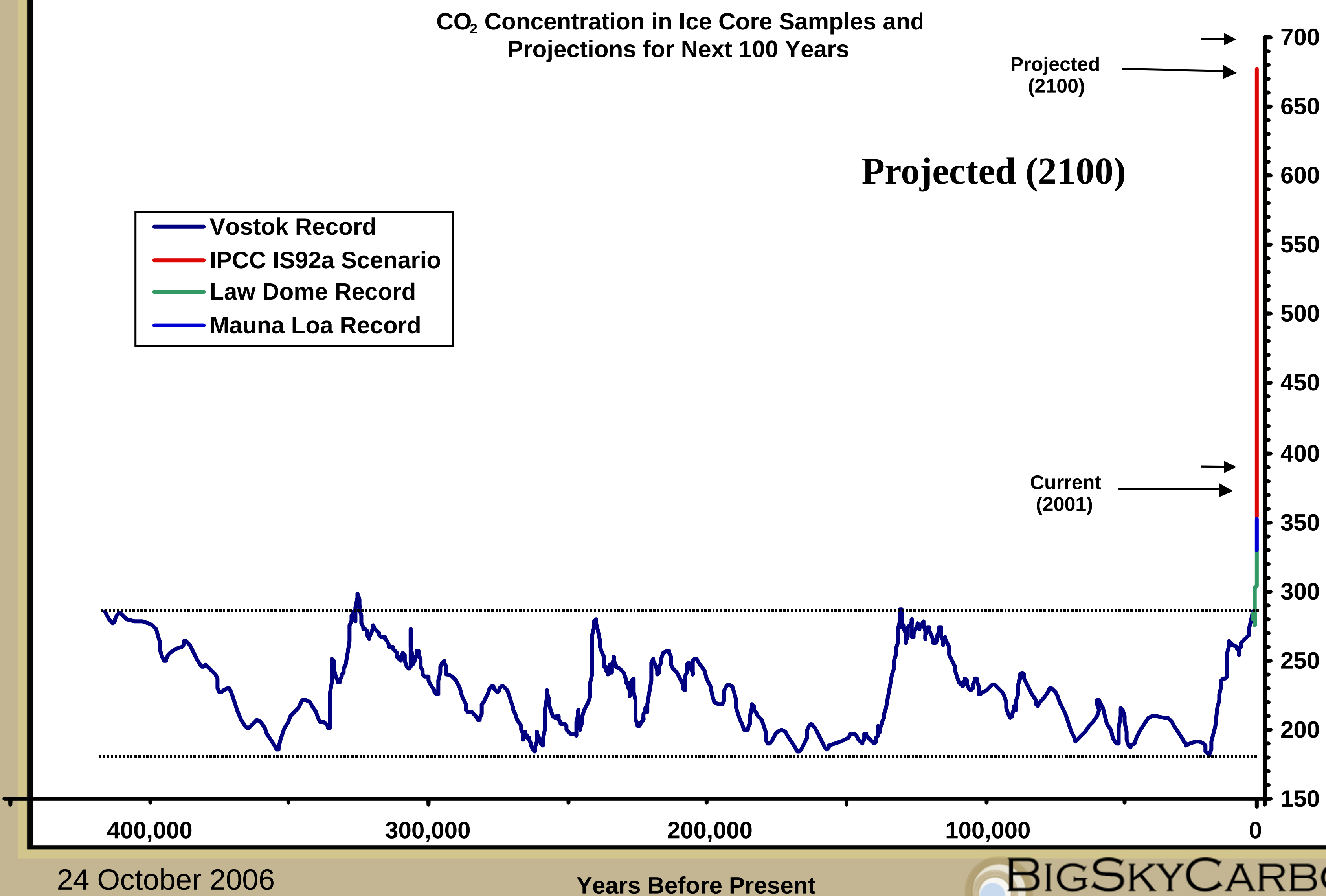
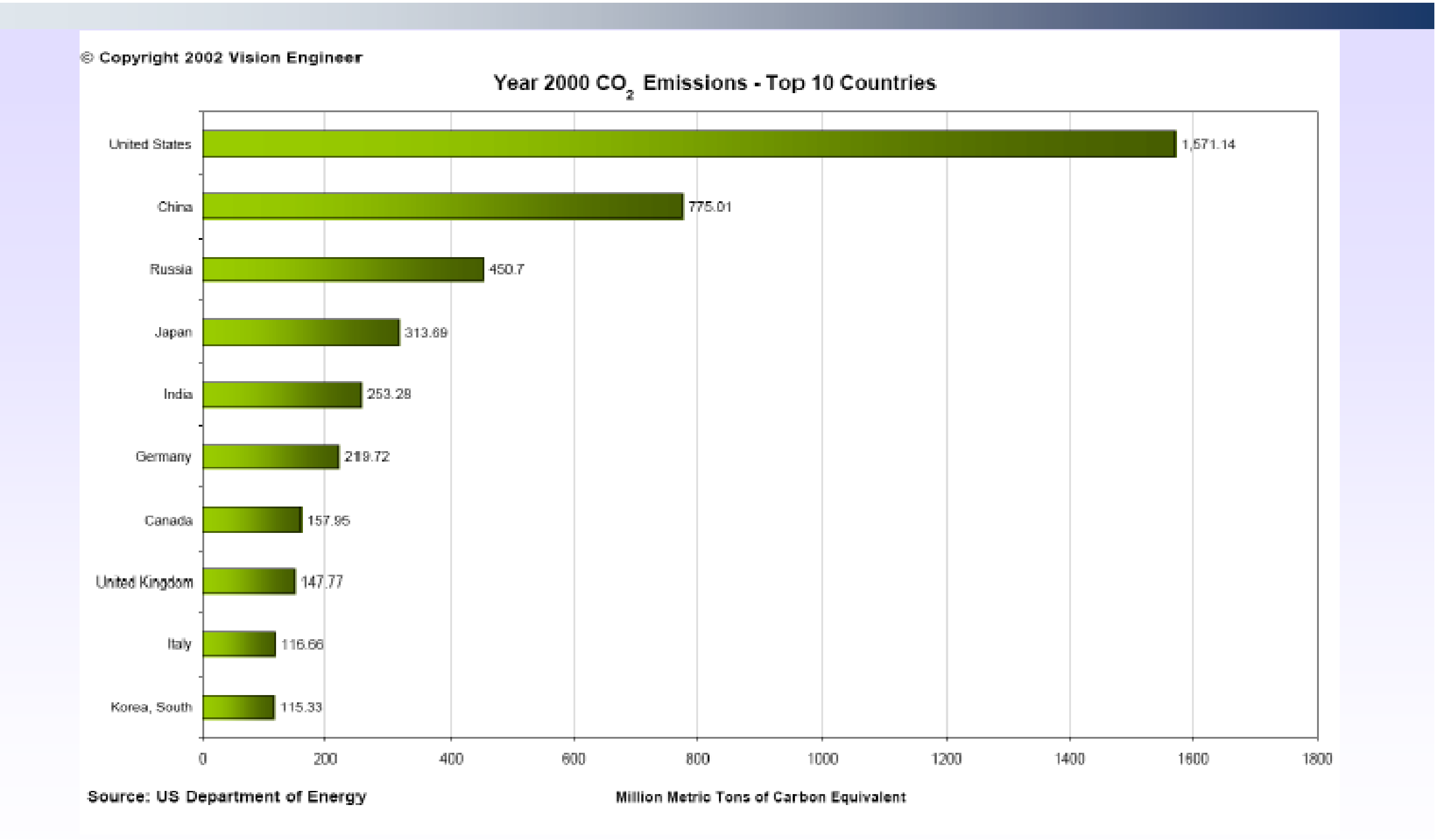
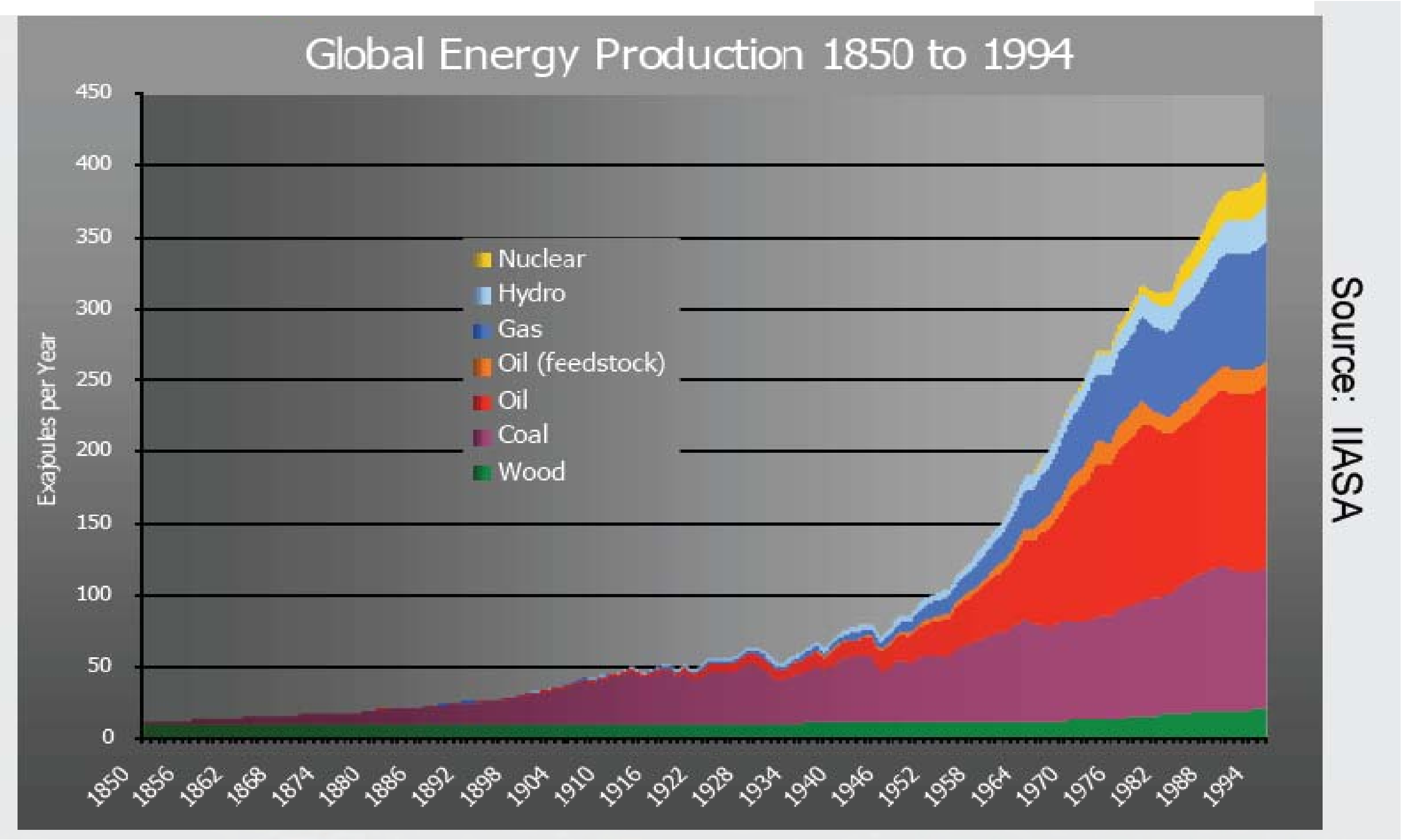
# $CO_2$ Concentration for Last 400,000 Yrs



# Carbon Emissions by Country



# Currently Global Energy System is Fossil Fuel Based



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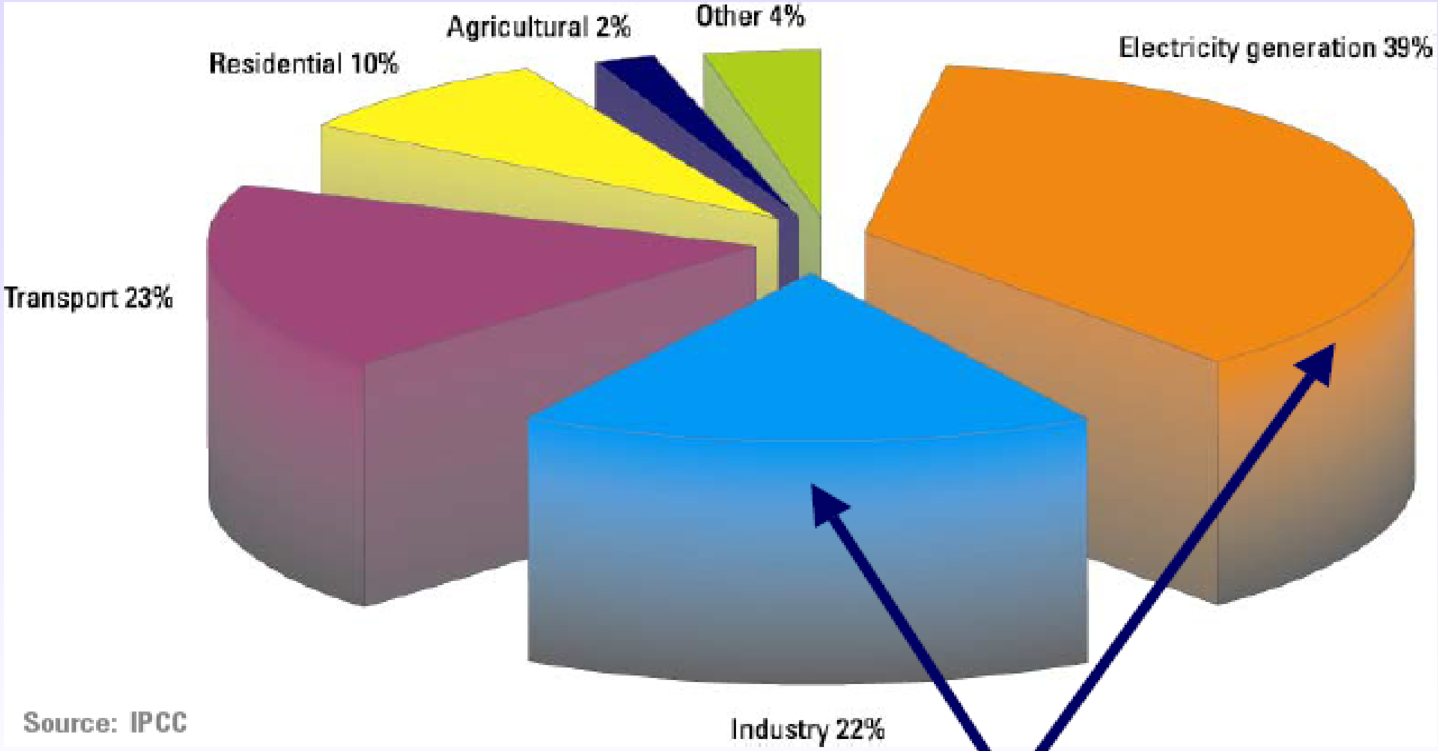
# $CO_2$ Sources by Category




CCS Focus is on stationary, large single sources

# Useful Conversions

- 1 ton C = 3.7 tons $CO_2$
- 1 gallon gasoline = 8.9 kg/$CO_2$
  - 3 gallons $CO_2$
- Atmospheric $CO_2$ = 380 ppm
- 1 ppm $CO_2$ (atmosphere) = 2.13 $GtCO_2$
- US emitted 6 Gton C in 2004
- 1 GW-yr coal power = 7-8 Mton $CO_2$

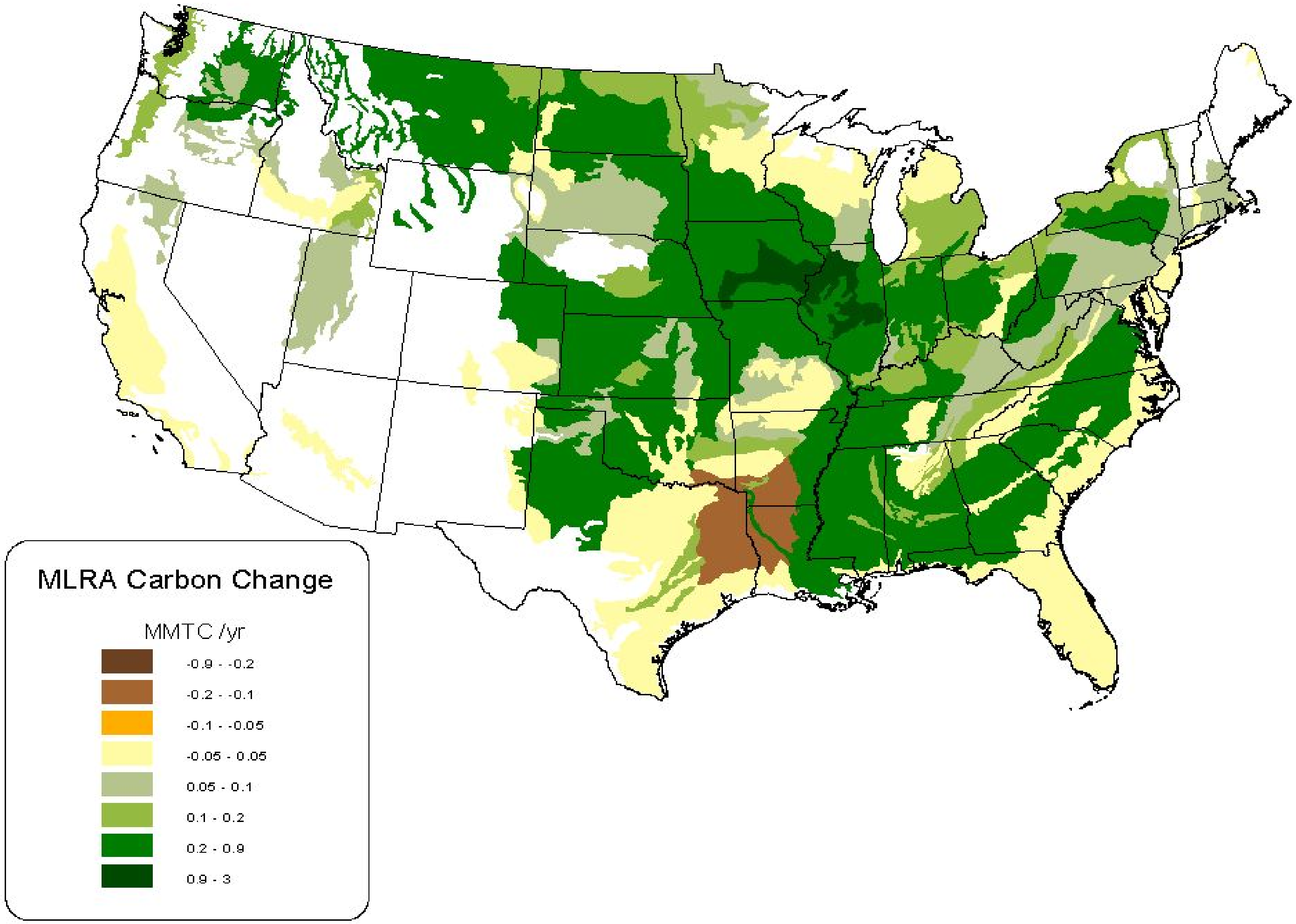
# There are Two Types of $CO_2$ Sequestration: Direct and Indirect

- Direct $CO_2$ sequestration involves capturing $CO_2$ at its point of generation before it is released to the atmosphere. The $CO_2$ is then put in long-term (hundreds to thousands of years) environmentally sound storage, usually in a deep geological formation.
- Indirect $CO_2$ sequestration involves capturing $CO_2$ that has already been released to the atmosphere. $CO_2$ is removed from the atmosphere through intake by plants or by fixing carbon in the soil.
- $CO_2$ sequestration: Increased use of renewable energy, and the efficient use of energy are some of the ways to address concerns about the potential climate effects of anthropogenic $CO_2$ .

# Terrestrial Sequestration

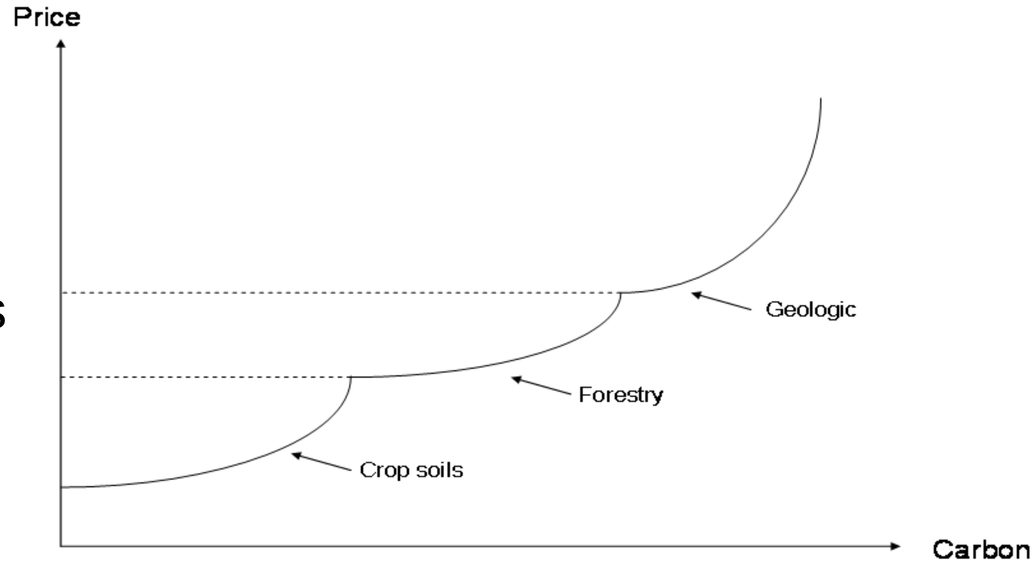
- Converting $CO_2$ into biomass
  - Increase soil carbon
  - Rehabilitate range land
  - Grow trees
  - Grow microbes
- Cost effective “low hanging fruit”

# Soil C Sequestration Potential (Century model) 21.2 MMTC $yr^{-1}$ on 149 Mha cropland



# Economic Analysis Objectives

- Assess economic potential for C sequestration in BSP region
  - Geologic
  - Terrestrial
    - Afforestation
    - Agricultural soils
    - Link to biofuels




- Assess potential for large scale deployment

# Geologic Sequestration

- The disposal of $CO_2$ in deep geologic formations
  - Depleted oil and gas reservoirs
  - Saline aquifers
  - Deep coal beds
  - ***Mafic rocks***
- Sequestration Processes
  - Hydrodynamic trapping → rapid, reversible
  - Solubility trapping → intermediate, less reversible
  - ***Mineral trapping → slow, permanent***

# Cost and Key Dates

- **Total Field Project Cost:** $6,238K
  - **DOE Share:** $5145.2K 84%
  - **Non-Doe Share:** $993.2 16%
  - *Does not include TBD cost share associated with Drilling, $CO_2$ purchase, and MMV.
- **Field Project Key Dates**
  - **Baseline Completed:** 11/30/2006
  - **Drilling Operations Begin:** 12/30/06
  - **Injection Operations Begin:** Fall 2007
  - **MMV Events:**
  - 3/31/2006 - Workshop
  - 6/30/2007 - Baseline MMV
  - 12/30/2009 - Post Injection Coring

# BSCSP Geologic Approach

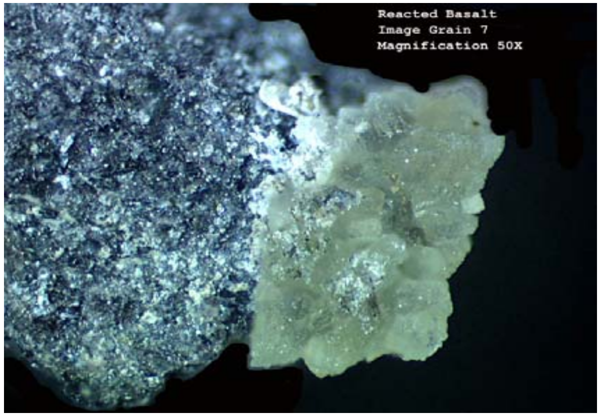
- Take advantage of reactive properties of $CO_2$
  - Identify sequestration targets with multiple trapping mechanisms (hydrodynamic, solubility, mineralization)
  - Emphasize mineral or other chemical reaction trapping
- Develop robust geologic sequestration options to permanently store $CO_2$
  - Conversion to alkalinity and carbonate minerals

# Reactive Trapping of $CO_2$

- $CO_2$ is converted to solid phase carbonate minerals (e.g., calcite) by accelerated rock weathering reactions

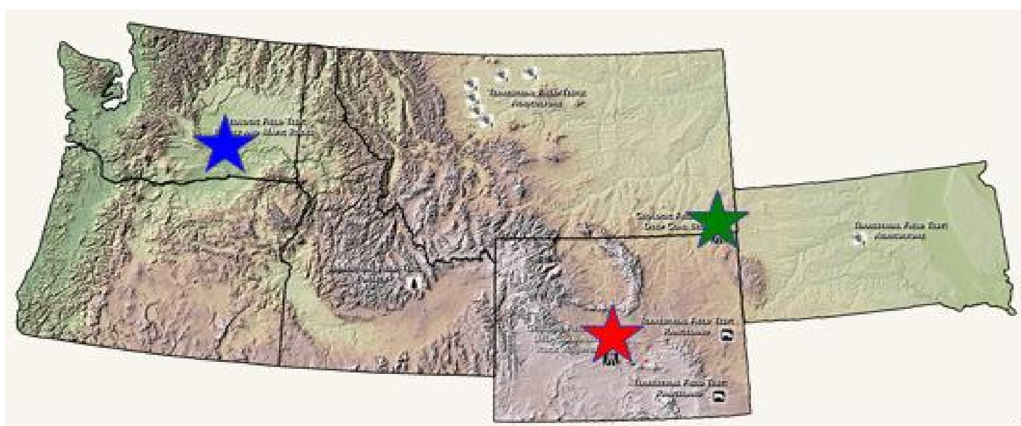
$$CaAl_2Si_2O_8 + H_2CO_3 + H_2O \rightarrow CaCO_3 + Al_2Si_2O_5(OH)_4$$

$$CaMgSi_2O_6 + Mg_2SiO_4 + 4H_2CO_3 \rightarrow Mg_3Ca(CO_3)_4 + 3SiO_2 + 4H_2O$$

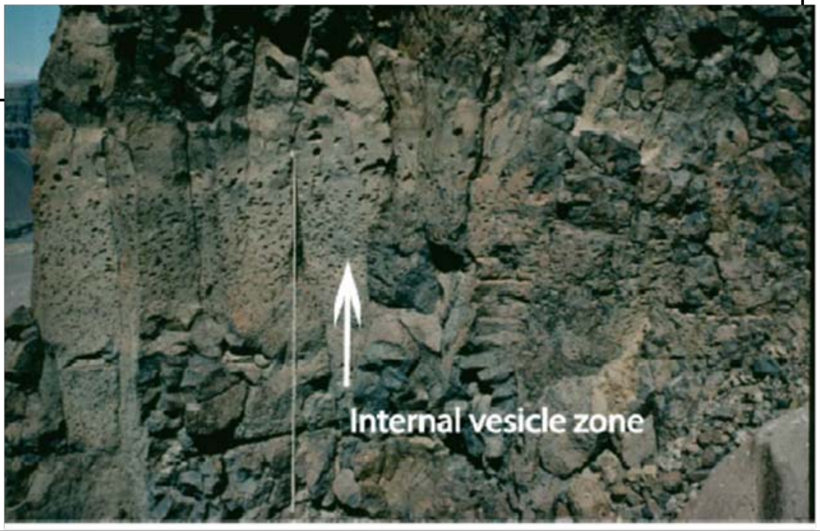


# BSCSP Geologic Field Activities

- **Basalt and Mafic Rock Field Validation Test**
  - **National Mafic Rock Atlas**
- **Reactive Carbonate Reservoir (Madison Formation) Field Validation Test**
- **Enhanced Coal Bed Methane Recovery and $CO_2$ Sequestration**

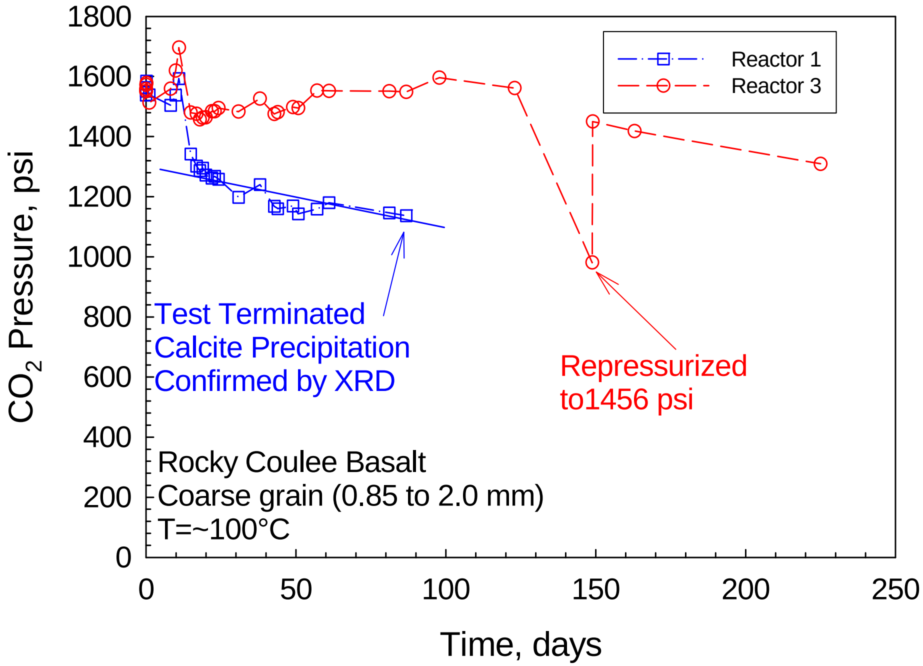


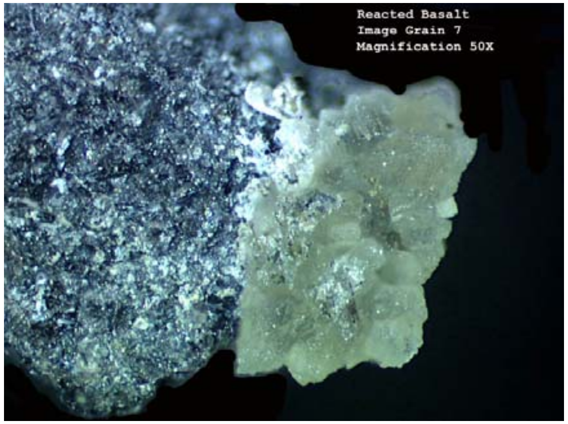
# Rationale for Basalts




- Capacity and Retention
  - Columbia River Basalt Group covers 164,000 $km^2$, >174,000 $km^3$
  - Chemical makeup favorable for mineralization reactions
  - Large capacity
    - ~100 $GtCO_2$ storage capacity (McGrail et al. 2006)
    - 33-134 $GtCO_2$ storage capacity (GWG methodology)

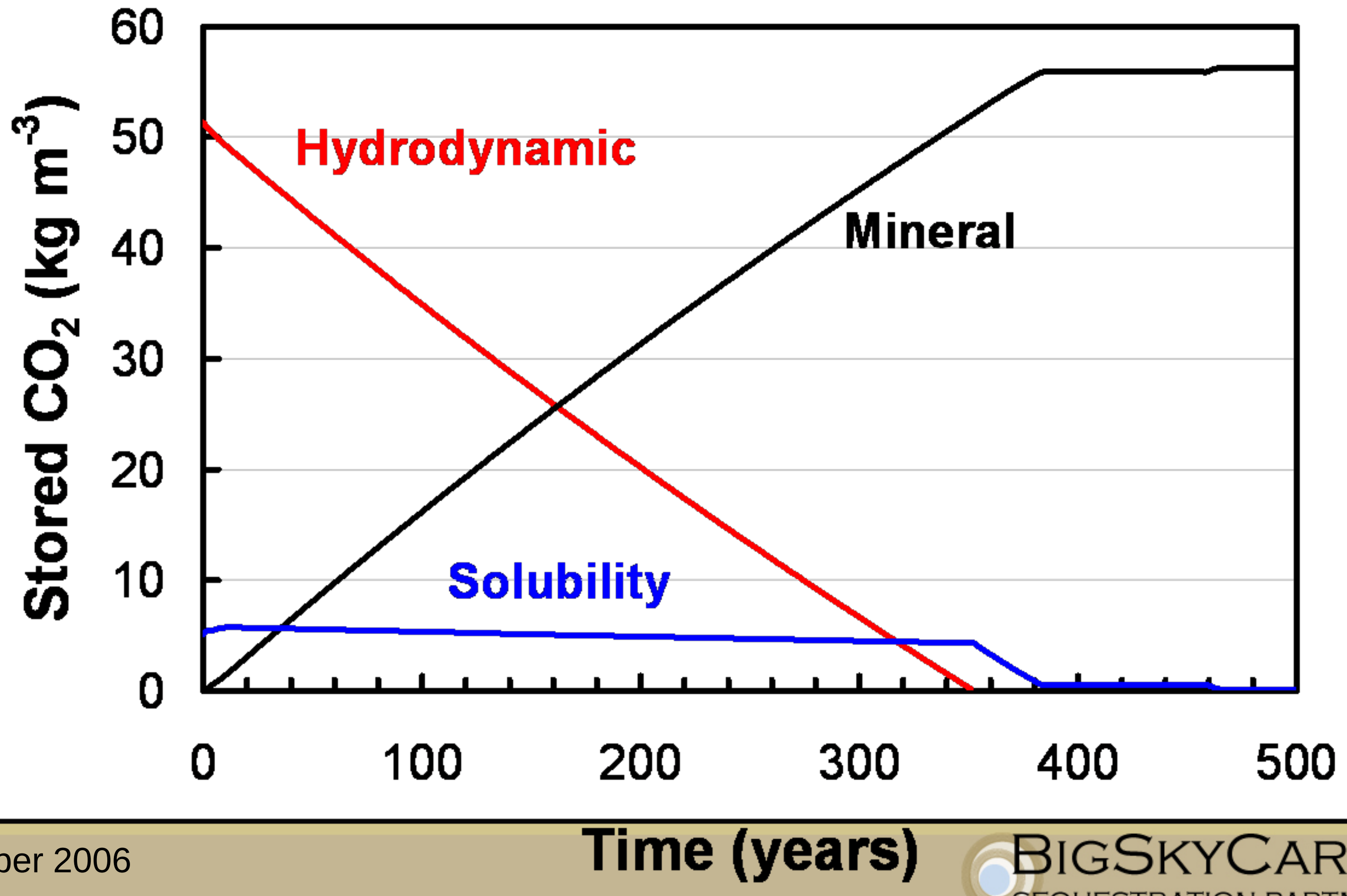
# Supercritical $CO_2$ Pressure Cell Experiments with Columbia River Basalt



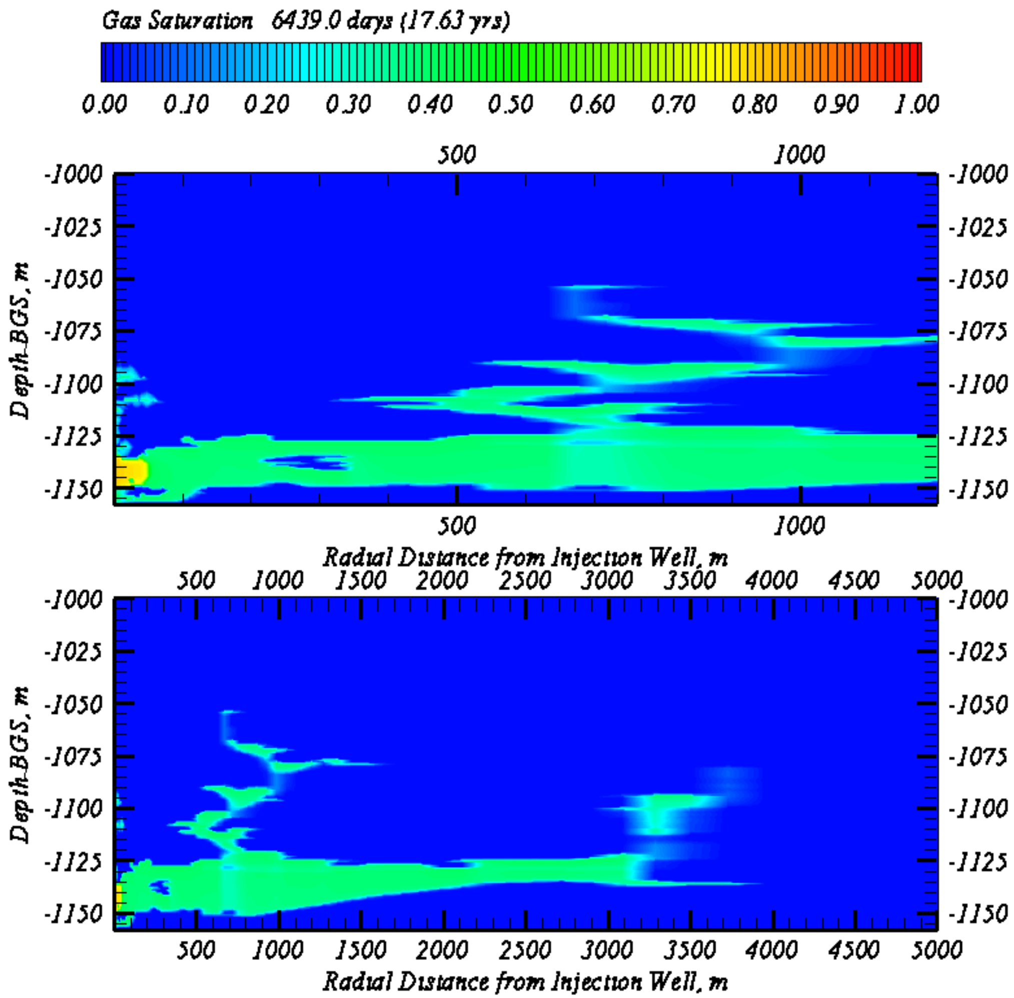




Long-term experiments showing transition from calcite to ankerite, Ca(Fe, Mg, Mn)$(CO_3)_2$

# Hydrodynamic, Solubility, & Mineral Trapping



# Supercomputer Simulation of $CO_2$ Injection in Grande Ronde Basalt



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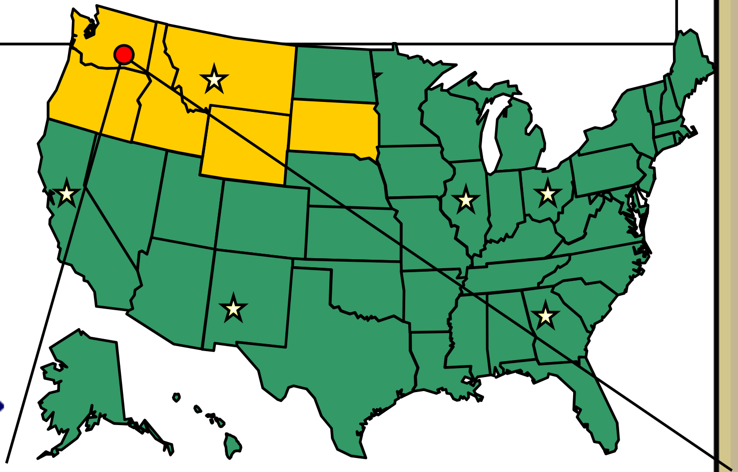
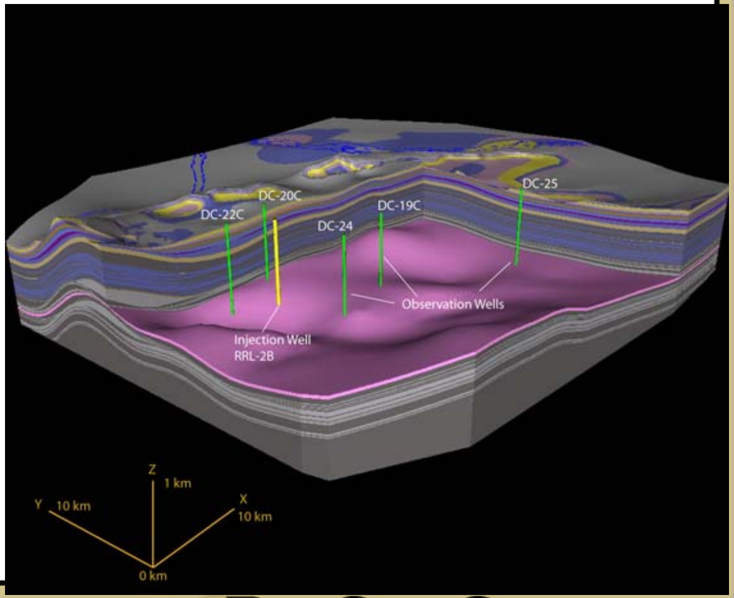
# Basalt and Mafic Rock Field Validation Test

- 3000 MT of $CO_2$ transported by rail from refinery
- Utilize existing deep well infrastructure to minimize drilling costs for injection and monitoring
- Target is Grande Ronde basalt formation (1100 m depth)
- Post injection core sampling to verify mineralization reactions
- Validate supercomputer simulations of $CO_2$ dispersion, dissolution, and trapping in basalt using suite of geophysical, hydrologic, and tracer methods





# CCS Involves Risk Assessment

How do we define risk?

Risk = Probability X Consequences

Risk = $f$ (probability, consequence)

Definition of Context

- What are the issues
- Who are the stake holders

Identify hazards

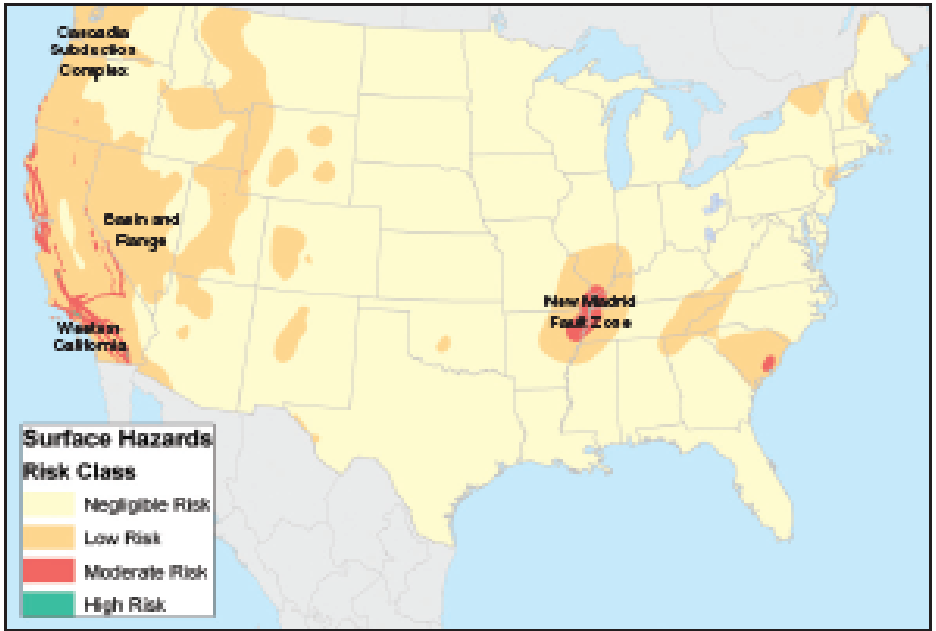
- What can go wrong

Assess the Risk

- Is it acceptable

# Easily Avoided Geologic Sequestration Risks

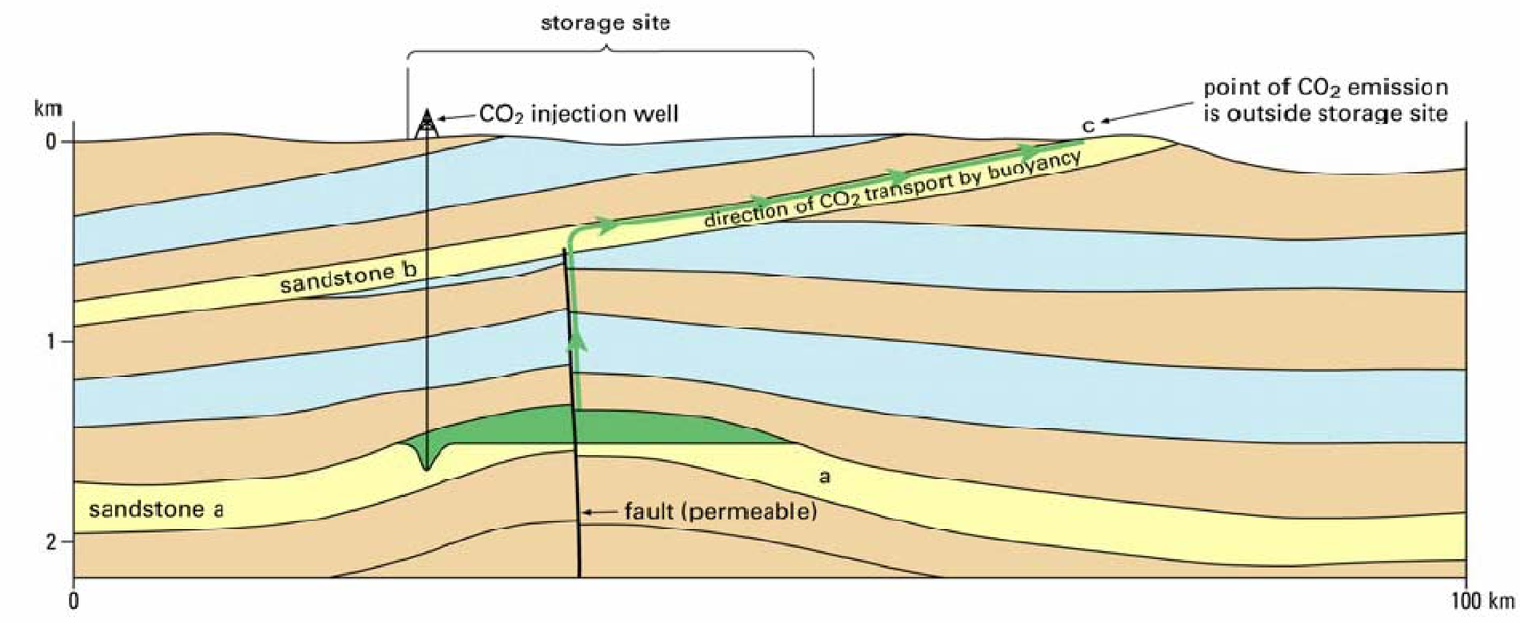
- Tectonically unstable
- Population centers
- National Parks
- Over pressured reservoirs
- Unstable mineral assemblages




By translating raw data about historic rates of seismic activity into a more meaningful measure of potential seismic risk to CCS infrastructure, we can see that relatively few regions of the United States have even moderate risk to CCS surface infrastructure.

# Potential Hazards in Geological Storage

- Poor geologic characterization
- Mobilization of saline formation fluids
- Incomplete monitoring
- Unidentified wells\poor completion
- Unknown chemical reactions
- Long-term stewardship



# Carbon Sequestration: General Modes

**Ocean Sequestration – risky, uncertain, and pricey**

- **Direct, deep-ocean injection --** ***high Ph, monitoring, NIMBY***
- **Biogeoengineering --** ***very risky, uncertain efficiency***

**Geological Sequestration – point-source limited (pricey)**

- **Saline Reservoirs --** ***infrastructure costs***
- **Old Oil/Gas fields --** ***containment risks***
- **Coal Beds --** ***infrastructure costs, tough to monitor***

**Soil/Plant Sequestration – low-volume and problematic**

- **No-till farming –** ***low volume, low retention, trading***
- **Adding biomass –** ***monitoring, short time frame, small volume***

**Chemical Sequestration -- pricey and dicey**

- **Creating terrestrial solids – expensive, energy intensive**
- **Creating hydrates – very risky, probably v. costly**
- **Basalt injection – untested technology, slow reaction rates**
- **Advanced concepts – unproven or developing technology**

# Path to Success in Risk Assessment?

- Do credible consequence analysis
  - Use the best tools we have to conduct the analysis
  - Never have risk assessment specialists separate from reservoir modeling
  - Focus on reasonable failure scenarios and avoid compounded worst case assumptions
  - Consequence analysis should be quantitative in terms of showing whether thresholds for environmental hazards are crossed
  - Address probabilities of occurrence but avoid the risk matrix paradigm
- Adhere to the effective communication guidelines when communicating the hazards analysis to the public
- ROTE EXECUTION WILL RESULT IN CERTAIN FAILURE

Slide from Pete McGrail